M2 internship subject – Study and optimization of energetic consumption of a post-processing chain for Continuous-Variable Quantum Key Distribution

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Context

Quantum technologies, i.e., the application of the laws of quantum mechanics for technological purposes, is a rapidly growing field [1]. Among the most mature technologies is **Quantum Key Distribution (QKD), which allows cryptographic keys to be exchanged between two trusted users.** These keys can then be combined with perfectly secure encryption algorithms to achieve invulnerable communications.

Nevertheless, in the field of quantum technologies, **initiatives are emerging to estimate and optimize the energy aspects of these technologies** [1]. Although some work exists in the field of quantum computing, the energy aspects of quantum communications remain understudied, even though the issue is central at a time when the first commercial systems are beginning to be deployed. Thus, **energy analysis is crucial for the scaling up of quantum communication networks**.

An initial study highlighted certain trade-offs and offered a comparison between the two main families of QKD [2] : namely, discrete variable (DV) protocols, which encode information on the properties of single photons, and continuous variable (CV) protocols, which encode information on the quadratures of the electromagnetic field and use coherent detectors. The latter are highly efficient at room temperature and have a significantly reduced energy cost compared to single-photon detectors.

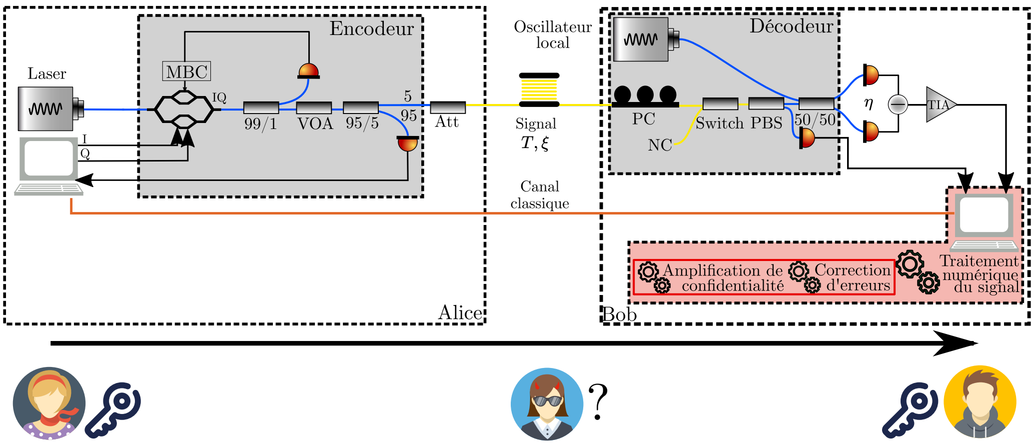

Figure 1 – Schematic diagram of a CV-QKD system implementation. The physical layer consists of a source, an encoder, a decoder, and a detector. The software layer consists of a digital signal processing chain and algorithms for error correction and privacy amplification.

This initial study is based solely on quantum hardware. However, QKD protocols also have a **classical algorithmic part**, which includes, in particular, error correction and privacy amplification (see Fig. 1). Thus, the energy analysis of the **classical** part of QKD is a necessary step in order to compare thedifferent systems.

Goals

The main objective of this internship is to implement techniques for quantifying the energy consumption of a complete CV-QKD system. The quantum hardware part has already been the subject of a previous study, and the intern will complete it with an analysis of so-called "classical" algorithms. In this sense, quantum technology skills are not required.

The intern will have access to state-of-the-art experimental platforms for quantum key distribution, error correction, and energy measurements, which will enable them to perform these measurements in various configurations and with various parameters. Typically, the intern will work on **computing nodes equipped with**

1. "Discovering quantum technologies" by Eleni Diamanti (QI team, LIP6) and Olivier Ezratty (2021) : `https://youtu.be/Hn6Gs-bqdOY?si=cg8O7eZq-36xnXpx`

multi-core CPUs and GPUs. For the energy part, the intern will use an innovative, high-resolution measurement platform, specially designed in-house.

The internship is divided into three main stages :

1. With the help of their supervisors, the intern will set up a complete communication chain for the CV-QKD. To do this, they will use open-source software such as AFF3CT [3], Cryptomite, or QOSST [4]. In this task, the intern will develop expertise in the communication system being studied.
2. **Le ou la stagiaire comparera la chaîne de traitement sur différentes plateformes matérielles en terme de débit et de consommation énergétique**. Il ou elle pourra par exemple évaluer la consommation de différents composants (comme des CPU ou des GPU). Des compromis entre vitesse de calcul et consommation énergétique sont attendus.
3. Based on previous results, the intern will propose optimizations for the processing chain. To do so, he or she will be able to rely on parallel programming techniques such as SIMD instructions or multi-thread programming.

Finally, the intern will participate in the design of a poster and a scientific article to present their results.

Work environnement

The intern will be at the intersection of two research teams. QI, on the one hand, is a team specializing in quantum information and, among other things, experimental quantum communications systems. ALSOC, on the other hand, is a team focused on the hardware and software aspects of embedded systems in the broadest sense. The candidate will therefore benefit from this dual expertise. The internship offers a major challenge that could have repercussions first in the world of research and then in industry. In this sense, the successful candidate will join a research environment within the LIP6 laboratory. **The intern will be able to interact with doctoral students from the research teams**. In particular, two doctoral students are currently working on the implementation of CV-QKD systems, but not from the perspective of energy consumption.

Expected skills

- Scientific curiosity
- C/C++ and Python languages
- Unix environment
- Knowledge of parallel programming (POSIX threads, OpenMP, StreamPU, etc.)
- Knowledge of SIMD programming (AVX, NEON, MIPP, etc.)
- Version control (Git)

Apply : PLease send an email to bot supervisors, namely yoann.petri@lip6.fr and adrien.cassagne@lip6.fr with at least a CV and the grades of M1 and M2.

Références

[1] Alexia Auffèves. Quantum technologies need a quantum energy initiative. *PRX Quantum*, 3 :020101, Jun 2022.

[2] Raja Yehia, Yoann Piétri, Carlos Pascual-García, Pascal Lefebvre, and Federico Centrone. Energetic analysis of emerging quantum communication protocols, 2025.

[3] Adrien Cassagne, Olivier Hartmann, Mathieu Léonardon, Kun He, Camille Leroux, Romain Tajan, Olivier Aumage, Denis Barthou, Thibaud Tonnellier, Vincent Pignoly, Bertrand Le Gal, and Christophe Jégo. Aff3ct : A fast forward error correction toolbox ! *SoftwareX*, 10 :100345, 2019.

[4] Yoann Piétri, Matteo Schiavon, Valentina Marulanda Acosta, Baptiste Gouraud, Luis Trigo Vidarte, Philippe Grangier, Amine Rhouni, and Eleni Diamanti. Qosst : A highly-modular open source platform for experimental continuous-variable quantum key distribution. *Quantum*, 8 :1575, December 2024.